

The biostratigraphy of Upper Albian – Lower Cenomanian *Aucellina* in Europe

By

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With 3 text figures and 2 plates

ABSTRACT

Upper Albian – Lower Cenomanian representatives of the bivalve genus *Aucellina* in cored boreholes were studied in eastern and southern England. Within the complex of taxa conventionally grouped under the invalid name *A. gryphaeoides* (J. de C. SOWERBY *non* SEDGWICK), two morphotypes/evolutionary lineages can be distinguished, analogous to the *pachti*–*cardissoides* “pairs” in the inoceramid *Sphenoceramus*. The *gryphaeoides* morphotype includes *A. gryphaeoides* s. s. and sensu POMPECKJ, *A. coquandiana* (D’ORBIGNY) and *Paraucellina krasnopolskii*. The *uerpmanni* morphotype includes *A. gryphaeoides* sensu WOLLEMANN and *A. uerpmanni* POLUTOFF, the latter being identified as the right valve

of the former taxon. *Paraucellina* is shown to be a junior synonym of *Aucellina*. A neotype for *A. gryphaeoides*, the type species of the genus *Aucellina* is proposed, and the age of its *stratum typicum*, the Cambridge Greensand, is discussed. Modifications of left valve shell ornament are shown to be of biostratigraphical use, as is the progressive tendency for the right valve umbo to become inflated. The biostratigraphy of *Aucellina* is reviewed in the context of nannofossil, foraminiferal and ostracod zonation, and tentative correlations are made between successions in England, north Germany and Poland.

KURZFASSUNG

Aus Kernbohrungen des östlichen und südlichen Englands stammende Vertreter der Muschelgattung *Aucellina* werden aus dem Zeitabschnitt Ober-Alb bis Unter-Cenoman untersucht. Innerhalb eines Formenkreises der bisher mit den nicht gültigen Namen *A. gryphaeoides* (J. de C. SOWERBY *non* SEDGWICK) belegt wird, können zwei Morphotypen bzw. Entwicklungslinien unterschieden werden, analog den beiden Arten *pachti* und *cardissoides* bei der zu der Inoceramidae zählender Gattung *Sphenoceramus*. Der *gryphaeoides* Morphotyp umfaßt *A. gryphaeoides* s. s. und sensu POMPECKJ, *A. coquandiana* (D’ORBIGNY) und *Paraucellina krasnopolskii* PAVLOV. Der *uerpmanni* Morphotyp schließt *A. gryphaeoides* sensu WOLLEMANN und *A. uerpmanni* POLUTOFF ein. *A. uerpmanni* POLUTOFF wird als rechte Klappe von *A. gryphaeoides* sensu WOLLEMANN angesprochen. *Paraucellina* ist ein jüngeres Synonym von *Aucellina*. Für *A. gryphaeoides*, die Typusart der Gattung *Aucellina*, wird ein Neotyp vorge-

schlagen; das Alter des *Stratum typicum*, der Cambridge Greensand, wird diskutiert. Veränderungen der Ornamente der linken Klappe sind von biostratigraphischer Bedeutung genauso wie die fortschreitende Wölbung des Wirbels der rechten Klappe. Die biostratigraphische Reichweite von *Aucellina* wird in Zusammenhang mit den Nannofossil-, Foraminiferen- und Ostrakoden-Zonierungen überarbeitet, ferner wird der Versuch unternommen, die Abfolgen in England, N.-Deutschland und Polen zu korrelieren.

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1. INTRODUCTION

The bivalve *Aucellina* is an important component of Aptian and basal Albian faunas throughout Europe, at many horizons occurring in flood abundance to the virtual exclusion of inoceramids. These early Cretaceous *Aucellina* include a large number of species, which have been extensively reviewed (e. g. PAVLOV 1907, SOKOLOV 1923), most recently by KEMPER (in press). After occurring in profusion in the basal part of the Lower Albian *Leymeriella tardefurcata* Zone, notably around Hannover, *Aucellina* disappears in the highest part of the zone (KEMPER, *ibid*), and there are no unequivocal records known to us from the *Douvilleiceras mammillatum* Zone, or from the Middle Albian. This considerable gap in the *Aucellina* record (and evolutionary history) appears to correspond to a period of high-diversity ammonite-rich faunas, and in particular to the range of the thin-shelled and morphologically analogous inoceramid *Birostrina*. With the disappearance of *Birostrina* in European successions in the *Hysterocheras varicosum* Subzone of the Upper Albian *Mortoniceras inflatum* Zone, *Aucellina* reappears at or near the base of the succeeding *Calliboplites auritus* Subzone, occurring in flood abundance in the lower part of the *Stoliczkaia dispar* Zone, and continuing into the basal part of the Cenomanian. *Aucellina* appears to die out towards the top of the *Neostlingoceras carcitanense* Zone, shortly before the point at which *Inoceramus crippsi* MANTELL enters, locally in flood abundance, at the base of the succeeding *Mantelliceras saxbii* Zone. It is noteworthy that these *Aucellina*-rich uppermost Albian and basal Cenomanian Gault and Chalk successions are characterised by low diversity faunas in which both ammonites and inoceramids are very poorly represented, particularly in the *dispar* Zone where only rare small very thin-shelled inoceramids tentatively assigned to *I. serotinus* PERGAMENT are present. *Aucellina* and inoceramids also appear to be mutually exclusive in Upper Albian successions in New Zealand and Australia (e. g. SPEDEN 1975; RAINE *et al* 1981).

The Upper Albian – Cenomanian *Aucellina* are usually known by the invalid name *A. [Avicula] gryphaeoides* (J. de C. SOWERBY) in FITTON, 1836, *non Avicula gryphaeoides* SEDGWICK, 1829, (= *Pseudomonotis speluncaria* (SCHLOTHEIM), a Permian bivalve). More recently, and particularly since the publication of the Treatise (1969), the name *Aucellina* [*Inoceramus*] *coquandiana*, (D'ORBIGNY), 1845, has tended to be used as a junior synonym of the invalid earlier name. The correctness of this assumed synonymy is examined below. *A. gryphaeoides* is the type species of the genus *Aucellina*, by subsequent designation (MARWICK 1939), the original author (POMPECKJ 1901) having proposed two type species, *A. aptiensis* (D'ORBIGNY) and *A. gryphaeoides*. *A. gryphaeoides* has been widely interpreted by Continental workers, the name being applied uncritically to almost any *Aucellina* of appropriate (Late Albian – Cenomanian) age, to such an extent that two quite distinct morphotypes have been unwittingly figured, e. g. by POMPECKJ (*ibid*) and by WOLLEMANN (1902) respectively. In addition to this complex of forms included in *A. gryphaeoides*, a number of other taxa have been described from Upper Albian – Cenomanian successions in Europe, such as *A. uerpmanni* POLUTOFF, 1933 from Poland and the Russian species *A. krasnopolskii* (PAVLOV), the type species of the genus *Paraucellina* PAVLOV, 1907.

The present paper describes an investigation of Albian – Cenomanian *Aucellina* in cored borehole and outcrop successions in southern and eastern England, as a result of which it has proved possible (1) to rationalise the present plethora of names and concepts applied, (2) to demonstrate the detailed biostratigraphy of the lineage/lineages represented in the context of macrofossil and microfossil zonation, (3) to demonstrate stratigraphically significant changes in ornament, which can be used in long-range correlation to distinguish between Albian and Cenomanian successions.

2. COMMENTARY ON RELEVANT ALBIAN – CENOMANIAN AUCELLINA TAXA

2.1 The type concept of *Aucellina gryphaeoides* (J. de C. SOWERBY)

J. de C. SOWERBY (*in* FITTON 1836), in describing *Avicula gryphaeoides*, figured (Pl. 11) two specimens from his own collection, neither of which can be found in the SOWERBY Collection in the BM(NH). The original of figure 3a is a phosphatised left valve steinkern with some shell attached from the

Cambridge Greensand at the base of the Chalk in the Cambridge area; a MS note with the original drawings (preserved in IGS archives), states that "better specimens are in the Geol. Society's Museum". This group of specimens (GSa 2326–2332) now in IGS, includes a steinkern (GSa 2329) with some residual shell in the umbonal region that is particularly well preserved, and comparable with the specimen figured: see this paper, Pl. 1, Fig. 7. Fig. 3b depicts a right valve (shell)

of a possibly unrelated form from the Upper Albian (presumed *dispar* Zone) greensand of Nurstead, Sussex.

The missing original of figure 3a was described as the typical form of the species by SOKOLOV (1923), but he did not formally designate it as lectotype. The topotype steinkern GSA 2329 in the IGS Geol. Soc. Coll. has a shell characterised by fine, close-set incised striae in the umbonal region, an ornament type described subsequently as "striate". A comparable type of ornament is exhibited by a group of well preserved bivalved shelled topotypes in the Sedgwick Museum, Cambridge, including the specimens figured by WOODS (1905); the best of these, and possibly the best specimen yet known, SM B21972 (WOODS Pl. 10, fig. 6; this paper Pl. 1, fig. 5), is herein selected as neotype of *A. gryphaeoides*, in the absence of SOWERBY's original specimen, and in view of the fact that SOWERBY gave only an inadequate MS indication of the availability of potential syntypic material.

It must be emphasised, as discussed subsequently, that the exact horizon and age of the neotype, as with any fossil from the complex sedimentary unit comprising the Cambridge Greensand, can never be known. It is not even certain whether the neotype is to be attributed to the *dispar* Zone at the top of the Albian or to the basal part of the Cenomanian *carcitanense* Zone, but it is unlikely to be older than this, to judge from the type of ornament.

2.2 *A. coquandiana* (D'ORBIGNY), 1846.

D'ORBIGNY described his *Inoceramus coquandianus* from a single bivalved phosphatised steinkern with some shell preserved on the left valve umbo. This specimen, in the Muséum d'Histoire Naturelle, Paris, came from an unspecified horizon in the Albian of Escagnolles (Var) France [Clar in D'ORBIGNY (1850)], and exhibits a style of preservation and ornament type comparable with *A. gryphaeoides* from the Cambridge Greensand. It cannot, however, be matched with any Cambridge Greensand specimen with this ornament type, differing particularly in the narrow right valve with its straight posterior margin and less inflated umbonal region. The assumed identity of *A. coquandiana* and *A. gryphaeoides* is open to question, and it is possible that the former is a related form of the *gryphaeoides* group, characteristic of southern European successions, and not necessarily of uppermost Albian – basal Cenomanian provenance.

2.3 PICTET & CAMPICHE (1868–71), Pl. 160, figured *Aucellina* assumed to be conspecific with *A. coquandiana* from St. Croix (figs 9a–c) and Yberg (figs 10a–d), Switzerland, these specimens being preserved in the Musée géologique de Lausanne and the Muséum d'Histoire naturelle, Geneva, respectively. The original of fig. 9 is a brown phosphatised bivalve steinkern from the Vracconien, or possibly from the base of the overlying Cenomanian, and is closer to the type of *A. coquandiana* from Escagnolles, particularly in respect of its narrow right valve, than it is to any presumably coeval Cambridge Greensand specimens. The original of fig. 10 is an unrelated *Aucellina* preserved in porous black phosphate probably conspecific with *A. maxima* WOLLEMAN, and thus of early Albian age.

2.4 POMPECKJ (1901) was unaware that *A. gryphaeoides* (J. de C. SOWERBY) was pre-occupied but considered that *A. co-*

quandiana was probably conspecific. Under *A. gryphaeoides*, he figured (ibid., pl. 16, figs 6a–c) a phosphatised steinkern from the "Lower Tourtia" of Langenberg bei Westerhausen (Harz), supposedly comparable with SOWERBY's Cambridge Greensand original. This relatively well preserved specimen (preserved in the Humboldt Museum für Naturkunde, East Berlin) has been examined by CJW, and proves to possess a relatively flat right valve umbonal region with a small anterior ear and a moderately straight posterior margin: it is thus distinct from *A. gryphaeoides* s. s. and may be more closely related to *A. coquandiana*. POMPECKJ also figured some small right valves with a well developed anterior ear from the "Tourtia" of Lüneburg.

In addition, he established the species *A. sanctiquirini* from some specimens (preserved in the Bayerische Staatssammlung, Munich) from the glauconitic Gault-Sandstein of St. Quirin on the Tegernsee, Bavaria, which he considered to be closely related, but to differ in several characters, notably the flatter, narrower right valve and the more massive left valve umbo; also the smaller anterior ear of the right valve and the shorter ligament surface of the left valve. We believe that *A. sanctiquirini* is more closely related to the group including *A. maxima* than to the *A. gryphaeoides* group, and could well be of early Albian age.

2.5 WOLLEMAN (1902) also figured what he considered to be *A. gryphaeoides* from the Cenomanian Tourtia of Lüneburg, but one of his figures shows a very different morphotype from that figured by POMPECKJ. WOLLEMAN's Pl. 3, fig. 2a depicts a relatively thick-shelled left valve with a marked posterior sulcus, and a shell exhibiting overlapping scale-like growth laminae which extend from the anterior to the posterior margin; the umbonal region of the shell displays a pronounced reticulate ornament resulting from the intersection of radial ribs with the concentric elements. To judge from material in the WROOST collection, Universität Hamburg, this morphotype is particularly well represented in the Tourtia. The second figure (fig. 3) shows a bivalved juvenile with equally developed anterior and posterior ears, of which the anterior was inclined downwards relative to the hinge line.

2.6 PAVLOV (1907) described the species *krasnopolskii* for small shelled left valves from greensands and phosphorites of presumed Cenomanian age exposed in the banks of the River Neroutch, and made it the type species of the new genus *Paraucellina*. *Paraucellina* is characterised by a well-developed protuberant anterior ear (in the left valve) which greatly exceeds the dimensions of the weakly developed posterior ear. PAVLOV drew attention to variation in his new species, noting that some, e. g. Pl. 6, figs 30, 40, were markedly oblique elongate, whereas others, e. g. fig. 41, were smaller and more nearly equidimensional. The specimen in fig. 40, refigured in the Treatise as *P. krasnopolskii*, closely matches the small specimen figured by WOLLEMAN (ibid., fig. 3a–d) in particular in the possession of a downturned anterior ear, and a clearly defined anterior ear. This specimen is in fact probably a juvenile stage of the form in fig. 39, which SOKOLOV (1923) subsequently called the typical form of the species, and differs fundamentally from the erect equidimensional form in fig. 41 (excluded from the type concept by SOKOLOV), which is characterised by a horizontal anterior ear and the absence of a posterior ear.

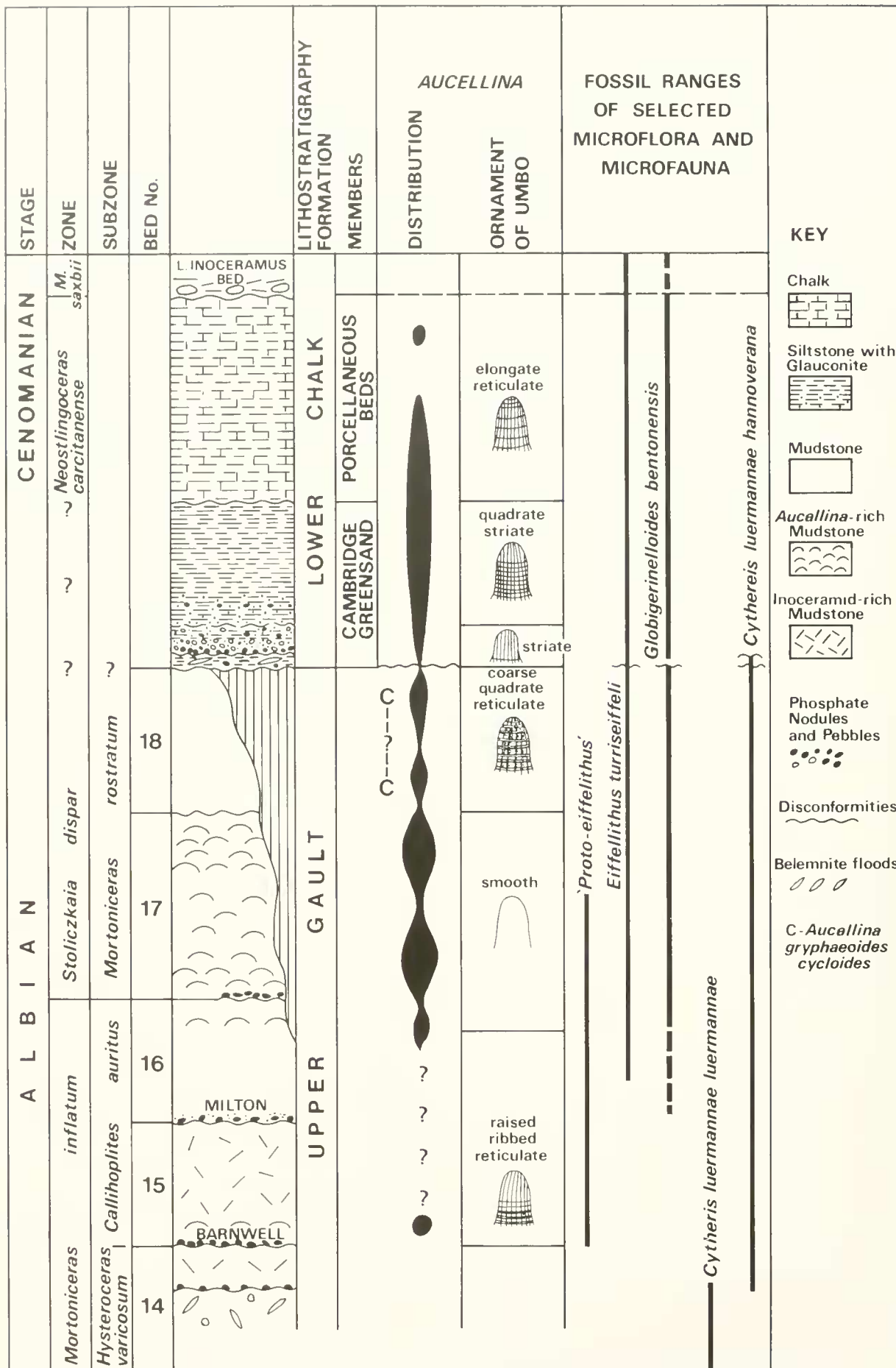


Fig. 1. The biostratigraphy of the succession in eastern England.

2.7 POLUTOFF (1933) erected the new species *uerpmanni* and a new variety of *A. gryphaeoides* (*A. g. cycloides*) from the uppermost Albian of the Sietetz borehole (Poland). *A. uerpmani* was described from right valves only, which were characterised by their disproportionally large anterior ear compared with that of *gryphaeoides* of comparable size, e. g. as figured by POMPECKJ (fig. 3) from the Tourtia of Lüneburg.

POLUTOFF was unable to identify any left valves that he could associate with his new species, but mentioned the presence of specimens comparable with *A. quaasi* WOLLEMAN. *A. gryphaeoides cycloides* was described from two incomplete right valves of unusually large dimensions (fig. 1), one an external mould with some shell adhering, the other upside down in the matrix.

3. STRATIGRAPHY

This study of the *Aucellina gryphaeoides* complex is based on several cored boreholes through unusually *Aucellina*-rich Upper Gault and basal Lower Chalk successions in eastern England, supplemented by data from Albian – Cenomanian Red Chalk outcrop successions at Hunstanton and Speeton, and from the Gault – Lower Chalk of the Channel Tunnel No. 1 (Aycliff) Borehole near Dover.

3.1 Eastern England

GALLOIS & MORTER (1982) have subdivided the Gault into 19 beds, with details of the zonal/subzonal classification, and the locations of the key boreholes. The thicknesses of the beds vary considerably: fig. 1 is a generalised succession, the Gault being largely based on the Mundford C Borehole (TL 76709132), with Lower Chalk details being taken from the Ely-Ouse Borehole No. 6 (TL 70277308). Attention must be drawn to Beds 15 and 17, characterised respectively by pieces of the large thick-shelled '*Inoceramus*' *lissa* (Seeley) and by a major *Aucellina* flood, which provide key litho/biostratigraphical markers. The faunas from Bed 16 upwards, with the exception of *Aucellina* and sporadic crinoid concentrations, are sparse and of low diversity, being dominated by thin-shelled pectinaceans and *Plicatula*. Rare poorly preserved ammonites indicate that the top of the succession is still within the *Mortonicerias* (*M.*) *rostratum* Subzone, the apparent absence of the uppermost Albian *Mortonicerias perinflatum* Subzone being confirmed by the absence of the ostracod *Cythereis luermannae bemerodensis* BERTRAM & KEMPER (see WILKINSON & MORTER 1981).

The Gault is overlain with erosive contact by the Cambridge Greensand, a thin unit of micaceous glauconitic silty marls with accumulations of phosphatised pebbles, including remanié fossils. Both indigenous (shelled) and derived (phosphatised with or without shell) fossils are present, including abundant *Aucellina*. The proven stratigraphical extent of downcutting ranges from high in the *auritus* Subzone (Bed 16) near Cambridge (M11 motorway section) to the *rostratum* Subzone (Beds 17 & 18) in East Anglia; however both SPATH (1943) and OWEN (1979) have reported remanié ammonites suggesting derivation from as low as the basal *auritus* Subzone (Bed 15) and as high as the *perinflatum* Subzone (i. e. post-Bed 19). It is possible that some of the phosphatised material of apparently basal *auritus* Subzone derivation came from a pit (Barnwell) which exposed a succession from Bed 15 up to and including the Cambridge Greensand, and was not necessarily of Cambridge Greensand provenance. The Cambridge Greensand thickens into East Anglia, where cored boreholes in most cases prove a bipartite subdivision

into a lower glauconite and phosphate-rich part in which the *Aucellina* include specimens in both phosphatised and non-phosphatised preservation; and a higher unit of greenish marls without phosphates which is rich in indigenous non-phosphatised *Aucellina*. The phosphatised pebbles in the lower unit are not randomly scattered, but occur as lags on winnowed erosion-surfaces which may prove to be correlatable. Locally, e. g. in Ely-Ouse Borehole 6, a thin basal unit of silty micaceous marls with *Chondrites* and sparse glauconite and phosphate is preserved. This bed contains abundant *Neobolites praecultimus* SPAETH, together with well-preserved (shelled) bivalves including oysters and *Aucellina*: the occurrence of common *C. luermannae hannoverana* (I. P. WILKINSON: pers. comm.) indicates a probable (Albian) *rostratum* Subzone age. The relatively condensed Cambridge Greensand near Cambridge has yielded *C. luermannae bemerodensis* (I. P. WILKINSON: pers. comm.), and may therefore be at least in part of *perinflatum* Subzone age, which would agree with the ammonite records. The conventional assumption that the Cambridge Greensand is a basal Cenomanian sediment containing derived Albian fossils is thus open to question, and an age-range for the matrix sediment from top *rostratum* to earliest *carcitanense* is equally possible. It must be emphasised that no indigenous ammonites are known from the Cambridge Greensand, and that the derived *Schloenbachia* discussed by CASEY (1965) are of possibly spurious provenance. The well-preserved bivalved shelled striate *Aucellina gryphaeoides* s. s. including the neotype probably came from relatively low in the Cambridge Greensand (i. e. from the lower of the two subdivisions) and could thus be of late Albian rather than Cenomanian age.

Above the Cambridge Greensand are the Porcellaneous Beds, a member of creamy coloured porcellaneous chalks with a low-diversity fauna dominated by *Aucellina* and small terebratulid brachiopods; *Aucellina* ranges throughout most of the succession and then cuts out, to reappear as a final flood some distance below the top. The higher part of the member yields poorly preserved ammonites including *Anisoceras*, *Hyphoplites*, *Idihamites* and *Schloenbachia*, suggestive of the basal Cenomanian *carcitanense* Zone.

The succession thins northwards, with the Cambridge Greensand being last proved in the cored IGS Marham Borehole (TF 70510803), and the Gault and Porcellaneous Beds condensing to form the Red Chalk and overlying „Paradoxia Bed“ of the Northern Province-type succession at Hunstanton (see PEAKE & HANCOCK 1961, fig. 4). The correlation of the (Cenomanian) Porcellaneous Beds, and the Paradoxia Bed is of particular significance; hitherto, in the absence of

ammonites, a Cenomanian age has been postulated for the latter unit solely on the basis of brachiopods thought to match the indigenous assemblage of the Cambridge Greensand (PEAKE & HANCOCK, *ibid.*, p. 303). Strong confirmation for a basal Cenomanian age for the Paradoxica Bed is, however, provided by a group of *Neohibolites ultimus* (D'ORBIGNY) in the LESTRANGE Collection in the BM(NH). An IGS borehole at Gayton (TF 7280 1974) showed the transition between the Gault and Red Chalk lithofacies, with the appearance of chalky limestones in the higher part of the Gault, and a marly chalk unit (Bed 19) overlying Bed 18 of the standard succession. Bed 19 carries a sparse fauna of *Aucellina* (including forms with striate ornament) and *Neohibolites praeultimus*, and is presumed to be of topmost *rostratum* Subzone age, on the basis of rare transitional forms between *Cythereis luermanne hannoverana* and *C. luermannae bemerodensis* in the higher part (I. P. WILKINSON: pers. comm.); it is overlain by a thin unit of splintery porcellaneous limestone with *Neohibolites praeultimus* which is in turn overlain by the Porcellaneous Beds.

To the North of Hunstanton, the succession expands, and at Speeton the Red Chalk facies extends into the Cenomanian. The Albian Lower Red Chalk succession is difficult to interpret, although a belt of inoceramid shell debris (see JEANS 1973, fig. 1) permits correlation with both the Hunstanton Red Chalk and the East Anglian Gault. The (Cenomanian) Upper Red Chalk equates lithostratigraphically and biostratigraphically with the Paradoxica Bed Porcellaneous Beds of East Anglia.

3.2 Southern England

Fig. 2 shows the standard top Upper Gault – basal Cenomanian succession as developed in the Dover – Folkestone area on the northern side of the Anglo – Paris Basin, the details being taken partly from OWEN (1976), and partly from unpublished data on the Aycliff borehole. Broad correlation exists between the East Anglian and Kent successions, notably the occurrence of thick-shelled inoceramid debris in PRICE Bed XI, and the *Aucellina* flood in the sandy glauconite- and phosphate-rich Bed XII, corresponding approximately to Bed 17. An erosion level with *Aucellina* equivalent to the base of Bed 15 (Barnwell Event) in East Anglia is present at Folkestone. This horizon was called the "Choanite Band" by old collectors and attributed by SPATH (1923–43) to Bed XII, although study of nannofossils from this band (A. W. MEDD: pers. comm.) shows that it lies in the lower part of PRICE Bed XI close to the *auritus* – *varcosum* subzonal boundary, a position substantiated by ammonites in IGS, BM(NH) and SM. The lower part of Bed XIII yields *rostratum* Subzone ammonites and *perinflatum* Subzone ammonites are known from the top 4m (OWEN, *ibid.*), the boundary between the Ob. *hannoverana* and *bemerodensis* ostracod Subzones falling within the bed (WILKINSON: pers. comm.). The Glauconitic Marl is closely comparable with Bed XII (and often confused with it), and is conventionally taken as the base of the Cenomanian (e. g. by CARTER & HART 1977); it rests with erosive contact on Bed XIII, locally, e. g. in the Aycliff borehole, at a relatively low level. It is rich in *Aucellina*, and yields no ammonites either indigenous or derived. The overlying pale coloured chalks carry a low-diversity fauna with *Aucellina*; sparse ammonite records (KENNEDY 1969) suggest a basal Cenomanian *carcitanense* Zone position.

4. MORPHOLOGY AND EVOLUTION

Study of *Aucellina* in continuous cored sequences has provided the necessary clues to unravel the diversity of taxa included in *A. gryphaeoides* s. l. (see previous discussion), and has also demonstrated a number of presumed evolutionary morphological changes, as well as changes in shell ornament.

4.1 Morphotypes

At any one horizon, 2 distinct morphotypes can be recognised, corresponding to *A. gryphaeoides* s. s./sensu POMPECKJ; and sensu WOLLEMANN respectively (see fig. 3).

(1) large, relatively thin-shelled, non- or weakly sulcate elongate oblique forms. Left valve with inturned anterior margin, small downturned anterior ear and distinct posterior ear; concentric ornament subdued, slightly oblique to long axis of shell, and tending to be restricted to anterior portion. Right valve with relatively small anterior ear. This morphotype includes *A. gryphaeoides* s. s.; *A. coquandiana* s. s. and sensu PICTET & CAMPICHE fig. 9 (only), *Paraucellina krasnopolskii* as restricted by SOKOLOV, and probably also *A. g. cycloides* POLUTOFF: it is named the *gryphaeoides* morphotype for convenience, notwithstanding the invalidity of the trivial name. The inclusion of *Paraucellina krasnopolskii* means that this genus falls into the synonymy of *Aucellina*. (It is unclear

whether *A. krasnopolskii* is a juvenile ontogenetic stage of *A. gryphaeoides*, or whether it is a separate species; in this context it may be significant that the condensed phosphoritic Albian – Cenomanian boundary successions in Poland and the USSR are said to be characterised by assemblages of small *Aucellina* including *A. krasnopolskii*, and that larger individuals are not normally present.)

(2) small, thicker shelled sulcate, equidimensional forms. Left valve with convex anterior margin, prominent horizontal anterior ear and indistinct or absent posterior ear; concentric ornament scale-like and prominent, continuing from anterior to posterior margin; strongly defined sulcus produces indentation of postero-ventral margin, the latter being thickened internally. Right valve with disproportionately large anterior ear relative to disc as in *A. uerpmanni*.

The association of right valves of *A. uerpmanni* type with left valves of *A. gryphaeoides* sensu WOLLEMANN in the Upper Red Chalk at Speeton, the Porcellaneous Beds, the Cambridge Greensand and the Glauconitic Marl and overlying silty chalks at Folkestone establish unequivocally the taxonomic position of *A. uerpmanni*, and it is accordingly used to name the second morphotype. The *uerpmanni* morphotype bears an amazing similarity to the Triassic genus *Pseudomo-*

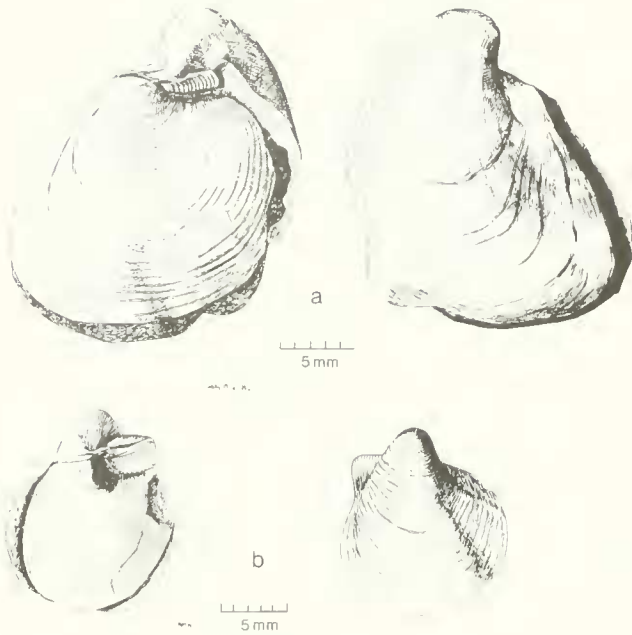


Fig. 3. Comparison between the two morphotypes of *Aucellina*. a) *gryphaeoides* morphotype: *Aucellina gryphaeoides* (J. de C. SOWERBY non SEDGWICK), neotype. Sedgwick Museum B21972. Cambridge Greensand of Cambridge. Illustrated photographically on Pl. I, Fig. 5. b) *uerpmanni* morphotype: *Aucellina uerpmanni* POLUTOFF. BM(NH) LL 40050. Glauconitic Marl of Folkestone. Illustrated photographically on Pl. I, Fig. 15.

notis (cf. the original use of *Avicula gryphaeoides* as applied to *P. speluncaria*), and an evolutionary relationship is not excluded. The Southern Hemisphere *A. cuglypha* WOODS is an even closer homeomorph of *Pseudomonotis*.

The existence of these two distinct *Aucellina* morphotypes is analogous to the *cardissoides* – *pachti* “pairs” and their derivatives in the Santonian – Campanian inoceramid *Sphe-*

noceramus, and is equally inexplicable. The *Aucellina* morphotypes could be viewed as (1) sexual dimorphs; (2) ecotypes of the same lineage; or (3) as two separate evolutionary lineages. This problem cannot be resolved at present. However, although adults of the two morphotypes are readily separable, particularly in the higher part of the sequence, it is in some cases difficult if not impossible to separate the earliest ontogenetic stages. It is noteworthy that comparable pairs of morphotypes occur in contemporaneous sequences in the Southern Hemisphere.

4.2 Sculpture

Aucellina left valve ornament varies in type according to the relative strength of the concentric and radial elements. The concentric elements are flanges, and/or raised growth-lines; the radial elements are either flat-topped wavy ribs separated by deeply incised grooves, or closely-spaced raised narrow rounded ribs, producing a characteristic corrugate cross-section to the shell. The two radial types characterise the *gryphaeoides* and *uerpmanni* morphotypes respectively.

There is a broad similarity in ornament at any one level (see fig. 1 and SEM photomicrographs on pl. 2), which may be used for biostratigraphical correlation. Both morphotypes exhibit smooth shells in Bed 17/XII in East Anglia and Kent at the base of the *dispar* Zone. A progressive morphological series with increasing strength of the concentric elements leading to a greater degree of reticulation, occurs through successive units of the Cambridge Greensand and Porcellaneous Beds and their lateral correlatives.

4.3 Inflation of right valve

Beginning high in the *rostratum* Subzone, there is a progressive increase in inflation of the umbonal region of the right valve and a concomitant increase in the size of the anterior ear. This trend is seen to an extreme degree in some of the latest forms of *Aucellina*.

5. BIOSTRATIGRAPHY AND CORRELATION OF AUCELLINA

Aucellina enters at the base of the *auritus* Subzone (base Bed 15) approximately coincident with a level of major macrofaunal and nannofloral turnover (the Barnwell Event). This is marked in particular by the appearance of primitive eifelithids (“*Protoeifelithus*”), thought to be evolutionary precursors of the long ranging *Eifelithus turrisseiffeli* (DEFLANDRE) (A. W. MEDD: pers. comm.). This fact established unequivocally that the beginning of the range of *Eifelithus turrisseiffeli* is not at the base of the Upper Albian as shown by THIERSTEIN (1973, fig. 23), and followed by all subsequent nannofossil workers, but well within the substage. THIERSTEIN (ibid., fig. 22) shows the true position of the sample from Bed XI at Folkestone.

There is an apparent gap in the *Aucellina* record until the top of Bed 16, where the genus reappears abruptly approximately coincident with the entry of *Globigerinelloides bentonensis* (MORROW), and continues in flood throughout Bed 17, which marks a major *G. bentonensis* acme. *G. bentonensis* is

usually considered to be a cold-water form, and it may be significant that the loss of ornament in *Aucellina* in Bed 17/XII coincides with the acme of this species. The abundance of *Aucellina* in Bed 17/XII presumably correlates with the entry of abundant *Aucellina* at the base of Ob-Alb 2 in the Hannover area (see Fig. 2).

Within the higher *rostratum* Subzone (Bed 18), a number of large *Aucellina* right valves have been found (see Pl. I, figs 10, 11), which are tentatively identified with *A. g. cycloides*; the types of which have not been examined.

Most successions studied do not extend beyond the top of the *rostratum* Subzone, at which level there is in many areas a change in lithofacies from mudstone to greensand/silty Gault. The *Aucellina* assemblages from the *perinflatum* Subzone in southern England are not well understood; this is due partly to poorer preservation in the coarse-grained sediment, and partly to possible ecological control of morphology. They do, however, bear some resemblance to forms from the basal unit

of the Cambridge Greensand. Similar difficulties of interpretation of *Aucellina* are encountered with specimens from the Flammenmergel facies in Germany.

The biostratigraphical complexity of the Cambridge Greensand and the probable level of occurrence within this unit of the well-preserved bivalved shelled striate *Aucellina gryphaeoides* s. s., including the neotype, has already been discussed. The advanced forms of *Aucellina* in the Porcellaneous Beds are also found in the Paradoxica Bed of Hunstanton, the Upper Red Chalk at Speeton and the post-Glauconic Marl *carcitanense* Zone chalks at Folkestone. In addition, these forms occur in the basal Cenomanian Rye Hill Sands near Warminster (Warminster Greensand, pars.), associated with *Neobibolites ultimis* and a *carcitanense* Zone ammonite assemblage including the zonal index. Further afield, advanced *Aucellina* occur in the basal Cenomanian Tourtia of Lüneburg, Germany, which allows the stratigraphical position of the forms described by POMPECKJ and WOLLEMANN to be identified in the absence of ammonites (SEM photographs pl. 2 fig. 7)

BERTRAM & KEMPER (1971) have recorded *Aucellina* from supposedly top Albian Bemeroder Schichten around Hannover; their material comprises juvenile ontogenetic stages which are difficult to interpret, but which exhibit strong ornament. The Albian age of these sediments is, however, questionable because the microfossil criteria used by them for defining the base of the Cenomanian – i. e. the extinction of *Doloclythere bosquetiana* (JONES & HINDE), *Neocythere stegbausi* (MERTENS) and the entry of *Pseudotextulariella cretosa*

(CUSHMAN) are taken in southern England (CARTER & HART, *ibid.*) to mark the base of Benthonic Foram. Zone 9 (see fig. 2), which corresponds to the base of the *Mantelliceras saxbii* Zone, i. e. the second ammonite zone above the base of the Cenomanian.

Finally, it is probable that *Aucellina* can be used to interpret the Sietz borehole in Poland. In this borehole the entry of abundant *Inoceramus crippsi* and *Schloenbachia* is taken to mark the base of the Cenomanian (POLUTOFF 1935) and the underlying *Aucellina*-rich beds are assumed to be Albian. However the occurrence of *A. uerpmanni* high in the succession above records of *A. g. cycloides*, strongly suggests that the "Albian" is in part Cenomanian, and equivalent to the Porcellaneous Beds/Lüneburg Tourtia, an interpretation supported by the entry of *Inoceramus crippsi* in flood in both eastern England and north Germany at the top of the beds with *Aucellina*, i. e. at the base of the *saxbii* Zone. It is thus likely that both in Germany and throughout eastern Europe the base of the Cenomanian has been drawn incorrectly: i. e., not at the base of the basal Cenomanian *carcitanense* Zone, but *within* the Lower Cenomanian at the base of the succeeding *saxbii* Zone.

The upper limit of *Aucellina* is given in the Treatise as Turonian. The evidence for this, however, is based on occurrences in New Zealand, in beds which have subsequently been reinterpreted as Albian and Cenomanian (RAINE, SPEDEN & STRONG 1981). On present evidence, there is no evidence that the genus occurs higher than the basal part of the Cenomanian.

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Plate 1

- Fig. 1. *Aucellina coquandiana* (D'ORBIGNY), holotype: a, view of left valve; b, view of right valve; c, view of anterior margin – all X2. Albian of Clar, Escragnolles (Var), substage uncertain. Muséum d'Histoire Naturelle, Paris, D'ORBIGNY Coll 272.
- Fig. 2. *Aucellina coquandiana* (D'ORBIGNY), specimen figured by PICTET & CAMPICHE Pl. CLX, Fig. 9: a, view of right valve X1; b, detail of umbonal region X4. Natural History Museum, Geneva no. 21400. Vracconien of Ste. Croix, Switzerland.
- Fig. 3. As above: another specimen on the same tablet from the same horizon and locality X1.
- Fig. 4. *Aucellina krasnopolskii* (PAVLOV), view of left valve X4; same specimen as figured on Pl. 2, Figs. 3 and 4. Sedgwick Museum B22009. Cambridge Greensand of Cambridge.
- Fig. 5. *Aucellina gryphaeoides* (J. de C. SOWERBY non SEDGWICK), neotype: a, view of left valve X1; b, view of right valve X1. Sedgwick Museum B21972; same specimen as figured on Pl. 2, Figs. 1 and 2. Cambridge Greensand of Cambridge.
- Fig. 6. *Aucellina* cf. *gryphaeoides*, variant showing some resemblance to *A. coquandiana*: a, view of right valve of phosphatic steinkern X2; b, view of left valve X2. IGS GSM 21112. Cambridge Greensand of Cambridge.
- Fig. 7. *Aucellina gryphaeoides* (J. de C. SOWERBY non SEDGWICK), phosphatic steinkern belonging to the group in the Geological Society's Museum cited by SOWERBY (in MS): a, view of left valve X2; b, view of right valve X2. IGS GSa 2329. Cambridge Greensand of Cambridge.
- Fig. 8. *Aucellina* sp. with very fine concentric ornament on right valve, and small anterior ear: view of shelled phosphatic steinkern X2. St. Albans City Museum (FORDHAM Coll.). Cambridge Greensand of Ashwell and Morden, Hertfordshire.
- Fig. 9. *Aucellina* cf. *uerpmanni* POLUTOFF, unusually large left valve for this morphotype X2. IGSBDM 6021. Cambridge Greensand of Ely-Ouse BH 6, Mildenhall, Suffolk.
- Fig. 10. *Aucellina* cf. *gryphaeoides cycloides* POLUTOFF: right valve X2. IGS BDB 8360. Upper Gault Bed 18 *Mortonicevas rostratum* Subzone, IGS Gayton BH, Norfolk.
- Fig. 11. *Aucellina* cf. *gryphaeoides cycloides* POLUTOFF: right valve X2. IGS BDN 3471. Upper Gault, Bd 18 *M. rostratum* Subzone, IGS Mundford C BH, Norfolk.
- Fig. 12. *Aucellina* sp.: right valve X2. IGS WM 4450. Upper Gault? Bed 18. *M. rostratum* Subzone, Severals House BH, Methwold, Norfolk.
- Fig. 13. *Aucellina uerpmanni* POLUTOFF: a, view of posterior margin of left valve to show sulcus X2; b, left valve X2. IGS Za 3805. Upper Red Chalk, Speeton, Yorkshire.
- Fig. 14. *Aucellina uerpmanni* POLUTOFF: left valve of juvenile specimen X4 IGS Hr 7331. Glauconitic Marl, *Neostlingoceras carcitanense* Zone, Channel Tunnel no. 1 (Aycliff) BH, near Dover, Kent.
- Fig. 15. *Aucellina uerpmanni* POLUTOFF: a, view of left valve X2; b, view of right valve X2. British Museum (Natural History) LL 40050. Glauconitic Marl, N. *carcitanense* Zone, Folkestone, Kent.
- Fig. 16. *Aucellina uerpmanni* POLUTOFF: left valve of juvenile showing concentric growth lines with raised flanges, sulcus well developed at posterior margin X4. IGS Za 3808, Upper Red Chalk, Speeton, Yorkshire.

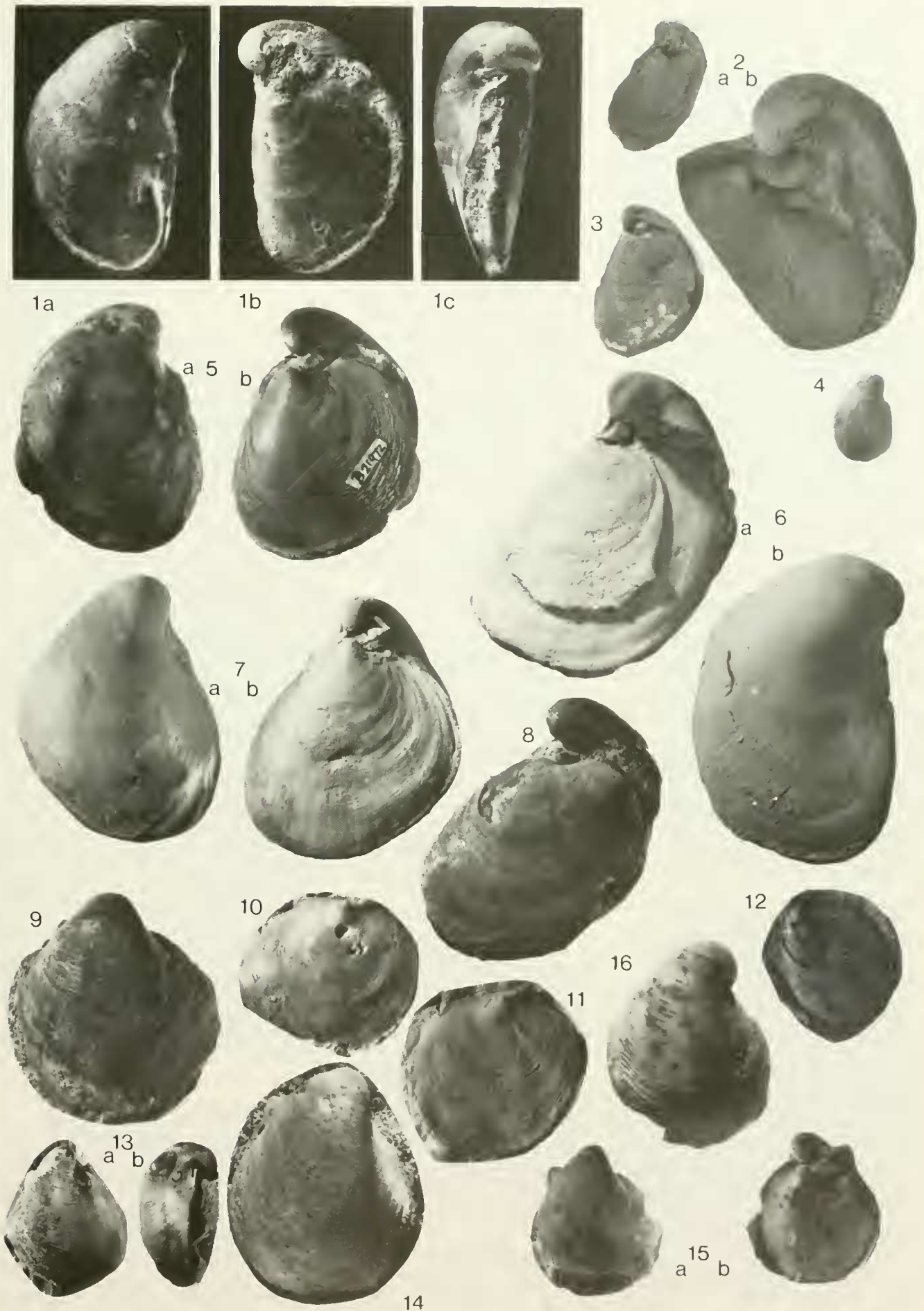
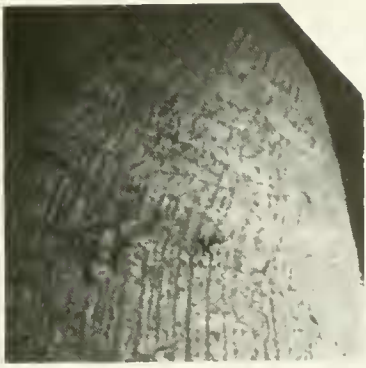


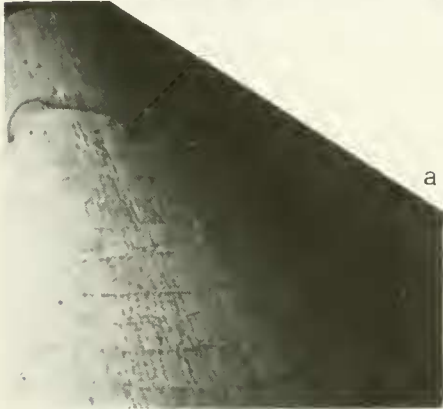
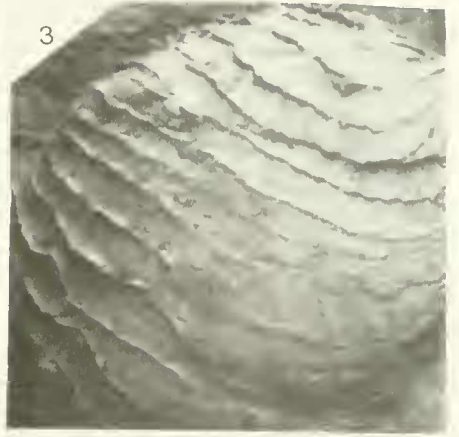
Plate 2

- Fig. 1. *Aucellina gryphaeoides* (J. de C. SOWERBY non SEDGWICK), neotype: a, left valve ornament (striate) X16; b, the same X79. Sedgwick Museum B 21972. Cambridge Greensand of Cambridge.
- Fig. 2. *Aucellina krasnopolskii* (PAVLOV): a, left valve ornament (quadrate striate) X9; b, the same X40. Sedgwick Museum B 22009. Cambridge Greensand of Cambridge.
- Fig. 3. *Aucellina* sp. (*gryphaeoides* morphotype): left valve ornament (coarse reticulate) X14. IGS BDN 3483. Upper Gault, Bed 18, *Mortonicerias* (*M.*) *rostratum* Subzone, IGS Mundford C BH, Norfolk.
- Fig. 4. *Aucellina* sp. (*uerpmanni* morphotype): a, left valve ornament (coarse reticulate) X23; b, the same X87. IGS BDC 576. Upper Gault, Bed 18, *rostratum* Subzone, IGS Marham BH, Norfolk.
- Fig. 5. *Aucellina uerpmanni* POLUTOFF (late form): left valve ornament (elongate reticulate) X43. IGS BDB 8310. Lower Chalk, Porcellaneous Beds, *Neostlingoceras carcitanense* Zone, IGS Gayton BH, Norfolk.
- Fig. 6. *Aucellina* sp. (late *gryphaeoides* morphotype): a, left valve ornament (elongate reticulate) X9; b, the same X67. IGS BDB 8301. Lower Chalk, Porcellaneous Beds, *carcitanense* Zone, IGS Gayton BH, Norfolk.
- Fig. 7. *Aucellina uerpmanni* POLUTOFF (late form): left valve ornament (striate reticulate). Unter-Cenoman Mergel (Tourtia), Lüneburg-Zeltberg, Germany (WROOST Coll., University of Hamburg).
- Fig. 8. *Aucellina* sp. (early *uerpmanni* morphotype): left valve ornament near umbo (raised ribbed reticulate) X30. IGS BDN 4614. Upper Gault, Bed 15, *Calliboplites auritus* Subzone, „*Inoceramus*“ *lissa* beds, IGS Mundford C BH, Norfolk.

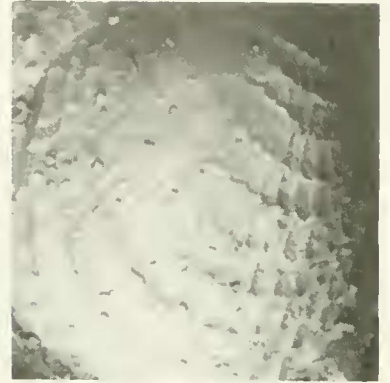
All figures are SEM photographs taken by the SEM Unit, British Museum (Natural History).



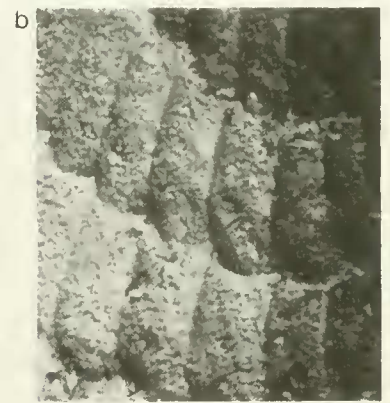
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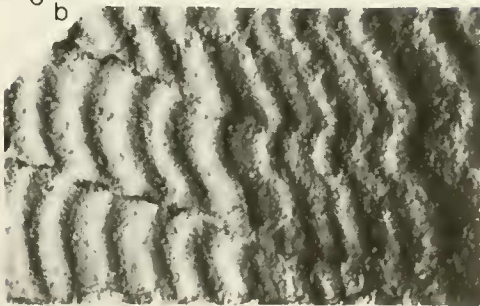
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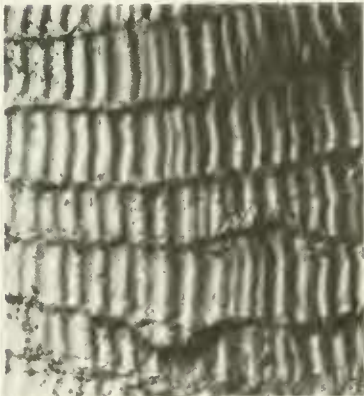
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a⁶



b⁶



5



7



8